FUNCTIONAL ANALYSIS OF DISTAL TIBIAL FRACTURES TREATED BY HYBRID EXTERNAL FIXATOR

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CERTIFICATE

This is to certify that this dissertation entitled **' Functional Analysis of Distal Tibial Fractures treated by Hybrid External Fixator'** is a record of bonafide research work done by **Dr. JEYA VENKATESH.P**, post graduate student under my guidance and supervision in partial fulfilment of regulations of The Tamilnadu Dr. M.G.R. Medical University for the award of M.S. Degree Branch II (Orthopaedic Surgery) during the academic period from 2011 to 2014, in the Department of Orthopaedics, Govt .Royapettah Hospital & Govt. Kilpauk Medical College, kilpauk, Chennai-600010

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DECLARATION

I, **Dr. P.JEYA VENKATESH,** solemnly declare that the dissertation, ‘**FUNCTIONAL ANALYSIS OF DISTAL TIBIAL FRACTURES TREATED BY HYBRID EXTERNAL FIXATOR '** is a bonafide work done by me in the Department of Orthopaedics, Govt. Kilpauk Medical College, Chennai under the guidance of Prof.R.Balachandran, M.S.Ortho., D.Ortho., Professor of Orthopaedic Surgery, Govt. Royapettah Hospital, Kilpauk Medical College, Chennai.

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Functional analysis of Distal tibia fractures treated with Hybrid fixator

Introduction: Management of distal tibia fractures remains a challenge. Treatment these fractures pose a therapeutic dilemma weather to give priority to anatomic reduction and articular congruity or to soft tissue healing.

Aim: The purpose of this study is to analyse the effectiveness of distal tibial fractures managed by hybrid external fixator .

Materials and methods: Prospective study of 25 patients (including 14 compound fractures) with distal tibial fractures treated with Hybrid external fixator.

Average age of patients was 43 years. There were 17 type A, 2 type B and 6 type C fractures as per AO classification. All patients were operated under image intensifier fibular fixation with k wire or plating was done in most cases, metaphyseal reduction was obtained and stabilised by olive wires and a ring construct is made in distal fragment, external fixator in the proximal fragment is connected to distal fragment in hybrid mode. Patients were followed up for average period of 12 months. All fractures united except one with an average time to healing of 21.1 weeks. Complications encountered were pin tract infection, delayed union, malunions, tendon impalement.

Results: Results were analysed using Ovadia & Beals

scoring system, there were 32% excellent, 44% good, 20% fair and 04% poor outcome.

Conclusion: Hybrid fixator is an effective method for Open fractures of distal tibia. It provides good access to soft tissue and wound care.The use of hybrid fixator as a definitive procedure for management of distal tibia fractures produces satisfactory functional outcome with limited complications.

KEY WORD: hybrid fixator, distal tibia, pilon fracture, open fracture.

INTRODUCTION

Distal tibial fractures are usually high velocity injuries with severe soft tissue damage. Management of these fractures pose a therapeutic dilemma weather to give priority to anatomic reduction and articular congruity or to soft tissue healing.

The poor soft tissue envelope, decreased vascularity of the region and accompanying soft tissue injury have challenged orthopaedicians with problems of malunions, delayed union, non-union and wound problems. Anatomic reduction of the articular surface, restoration of alignment, and early ankle joint mobilization has been shown to be effective in managing most distal tibial fractures.

The various modalities of treatment includes open reduction and internal fixation, initial joint spanning external fixator followed by plating, hybrid external fixator and Ilizarov fixator application. Whichever method of stabilization is chosen, the construct should be sufficiently stable to maintain the reduction. The wound healing problems and infection should be decreased by careful soft tissue management & not operating through compromised soft tissue.

AIM OF THE STUDY

To analyse the functional outcome of distal tibial fractures managed surgically with hybrid external fixator as a definitive management.

REVIEW OF LITERATURE

HISTORICAL REVIEW

Fractures have been recognized and well recorded in history. Knowledge of fracture treatment dates back to Egyptian mummies of 2700 BC.

External splintage was the only option for the management of fractures for thousands of years. 5000 years ago, the Egyptians used palm bark and linen bandages. Wood , Clay and lime mixed with egg white were used.

In 1897, the first modern external fixator was developed by Dr Clayton Park Hill. In 1906, Dr. Albit Lambotte designed a similar external fixator. In 1934, Dr Roger Anderson developed a frame with transfixation pins. In 1938 Dr. Raoul Hoffman invented the Hoffman fixator, which was later modified into the Hoffman Vidal system by Dr. Vidal and Dr. Adrey by using multiplanar frame to increase the rigidity. However, this frame was too rigid and static and thwarted union.

Pilon is a French term used to describe a fracture of the distal tibia. Destot coined the term pilon, as he thought that the distal tibial metaphysic resembled a pharmacist's pestle. Plafond is a French term described by Bonin, Referring to the distal tibial articular surface as the roof of the ankle joint.

In a study of 84 patients, that established the open reduction and internal fixation with screws and plate as the standard, the authors with a nine year follow up reported 74% good functional results. The principles of treatment included

1. Re-establishment of the fibular length.

2. Re-construction of the lower articular surface of tibia.

3. Placement of metaphyseal bone graft; and

4. Stabilisation of the medical aspect of tibia using a plate.

Of the 84 fractures, 60 were secondary to low energy skiing injuries. 90% of the patients returned to their pre-injury occupations.17 A series of 26 patients were divided into 2 groups based on fracture pattern. Type A fractures with twisting injuries with little comminution, whereas Type B fractures were more severe injuries, with a crush component. On treatment with open reduction and internal fixation, 65% cases had good to excellent results. Better results were obtained in Type A fractures (84%) than B (53%). Crucial factors besides fracture type were the length of immobilization and quality of reduction. Prolonged immobilization resulted in poor outcome, showing the need for stable fixation to permit early mobilisation[1].

A retrospective clinical review of 42 patients treated with open reduction and internal fixation demonstrated the importance of using a logical classification system in describing the outcome of fractures of the distal tibia. The results of this study have clearly demonstrated that Types I and II (Ruedi and Allgower) are amenable to open reduction and stable internal fixation with an 80% success rate. The Type III fractures present a much more difficult problem; a satisfactory outcome was present only in 6 of the 19 patients (32%) in this study[2].

A high energy pattern correlated with a higher incidence of wound healing complications. This inference was obtained in a large series of patients (145) in which 46% were high energy injuries. Eighty patients underwent open reduction and rigid internal fixation whereas others underwent other procedures like closed reduction and cast (32), calcaneus pins and plaster (8), fibular stabilization and cast (3), limited internal fixation and external fixation (5). They had 34 fractures equivalent to Ruedi and Allgower Type III and good to excellent results were achieved only in 47% of the patients[3].

A series reported disastrous results when inadequate and unstable fixation was used to treat the distal tibial fractures. They had 36% rate of skin sloughing and a 55% infection rate[4].

A randomized prospective study involving two groups of patients, one (18) who underwent open reduction and internal fixation and the other group (20) who underwent external fixation, showed no significant difference. However, because of the relatively greater number of complications in the internal fixation group, with no significant difference in outcome, they concluded that limited internal fixation combined with use of external fixator was an equally effective and safer alternative[5].

Follow up evaluations of 34 distal tibial fractures showed that results of operative treatment are dependent on the severity of the initial trauma, the quality and stability of the reduction. The mechanism of injury, soft tissue status, the degree of comminution and articular damage affect the long term outcome. 65.4% of Type II fractures had excellent results, 11.5% adequate and 23.1% had poor results. In Type III fractures, only 20% had excellent, 12.5% adequate and 37.5% poor results[6] .

By using a trans articular delta-framed external fixator with limited internal fixation, they were able to achieve adequate fixation and good fracture union with no infections or skin sloughs and only 2 minor pin tract infections. Of the 20 patients treated, six had good to excellent results, nine had fair and five poor results[7].

In a study of 48 patients using hinged transarticular external fixator, they reported that post operative complications were minimal with no cases of superficial or deep wound infection or dehiscence. They obtained 70% excellent to good results. The main limitation of this technique appeared to be in obtaining an excellent articular reduction. Although unknown, this limitation may have had significant effect on the long term clinical outcome[8].

Using the technique of hybrid external fixator, seventeen patients with distal tibial fractures gave 69% good results and major complications were avoided. Without crossing the ankle joint, tensioned 2mm wires were placed in the distal tibia with half pins more proximally in the tibia. Patients with Ruedi and Allgower Type II and III fractures were treated with skeletal traction, and surgery was performed when oedema resolution had occurred[9].

Patients with severe intra-articular fractures of distal tibia were treated with internal fixation. Tibial length was maintained by an articulated external fixator. Fibula fracture was fixed internally.

67% of the patients had good to excellent results. This technique was less invasive than open procedures that required the use of a tibial plate especially in open fractures[10].

A study of 36 patients using the Hybrid External Fixator achieved 67% acceptable injuries in the high energy fractures treated. There were three cases of osteomyelites, one skin slough and five pin tract infections[11].

Stability like that of open reduction and internal fixation was observed in fourteen patients treated with Hybrid external fixators. They had 64% acceptable results and mean union time was 13 weeks. They concluded that a Hybrid External Fixator is useful, particularly in comminuted fractures where anatomic reduction cannot be expected despite open reduction[12].

In a study of 63 patients treated with Hybrid External Fixator (34) and internal fixation (27), the authors noted that the patients treated with Hybrid External Fixator had lower clinical scores, a higher rate of complications, more nonunions, malunions, slower return to function and more infections. They concluded hybrid fixation did not seem to rectify the problems inherent to severely comminuted distal tibia fractures[13].

In a retrospective review of 60 patients, to evaluate whether treatment with open reduction with internal fixation was better than external fixation methods in achieving fracture union, there were no statistically significant differences in complication rates. High degree of malunions occurred with fractures treated with external fixators. They concluded that external fixation addresses soft tissue compromise associated with distal tibial fractures, but malunion is a recognised complication[14].

In a series of patients treated with Hybrid External Fixator the authors concluded that Hybrid External Fixator reduces the number of iatrogenic complications associated with open reductions and internal fixation. The Hybrid External Fixator had proved to be a safe, reproducible and effective treatment modality in fractures of distal tibia[15].

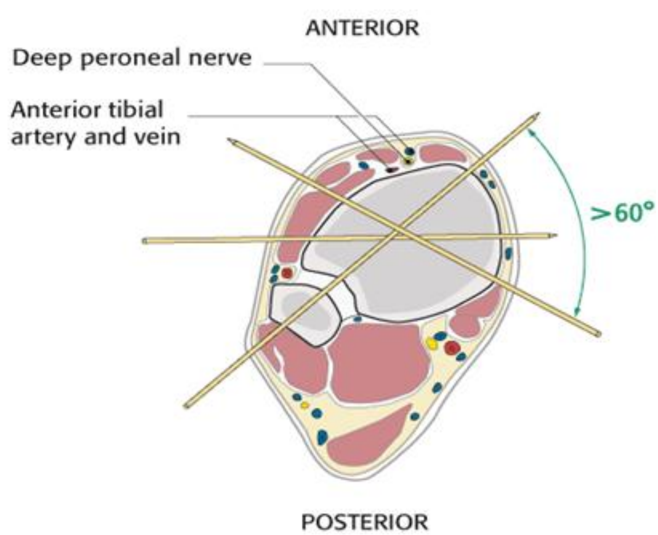
In a study to determine effect of different constructs of Hybrid External Fixator on the mechanical environment of the fracture site, the authors opined that the bar ring hybrid fixator that simply connected a unilateral fixator to a wire or ring assembly was very flexible. Reinforcing the bar ring hybrid fixator with diagonally placed struts eliminated the deforming forces[16].

In a review of 24 patients, Anglen concluded that hybrid fixators are can be used for the treatment of distal tibia fractures as they provide rigid fixations with minimal soft tissue injury[17].

SURGICAL ANATOMY OF DISTAL TIBIA

Distal tibia region is described as the area extending 5 cm from the tibial plafond. The articular surface of distal tibia is rectangular in shape and form the roof of the mortise. The strongest cancellous bone in the distal tibia region is located near the subchondral bone plate and may provide optimal area for fixation devices. Maximum compressive strength of tibial plafond occurs within approximately 3 mm from articular surface.

Figure 1 Safe zones of distal tibia for pin insertion



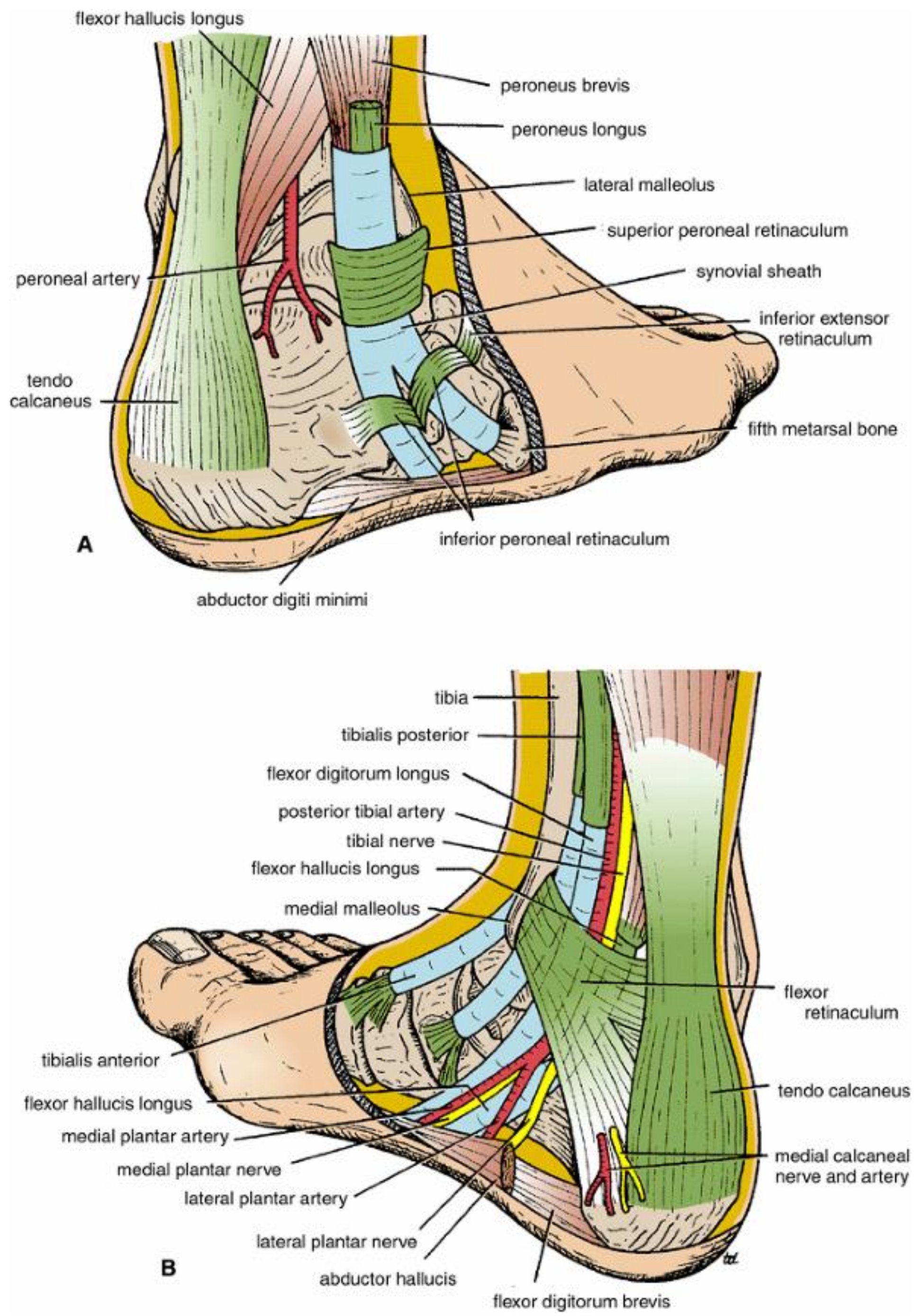


Figure 2 Structures around ankle

Borrelli et al[18] have described the extraosseous blood supply of tibia using cadaveric injection techniques. Distally the anterior tibial artery gives off several medial and lateral arterial branches that pass onto the surface of the anterior distal tibial metaphysis. The posterior tibial artery provides the majority of the extraosseous vasculature to the medial and posterior aspects of the distal tibial metaphysis. On the medial aspect of the distal tibia, these branches anastamose with branches from the anterior tibial artery and form a complex vascular network. This extraosseous blood supply is at risk for disruption during the injuries process, but is also at risk for disruption during the injurious process, but is also at risk during plate applications to the distal tibia.

The periosteum is a nidus for the ramification of the vessels prior to their distribution in the bone; hence responsible for bone exfoliation or necrosis when denuded of this membrane by injury. Preservation of periosteum enhances the rapid bony union thus favouring use of biological plating or stable external fixator constructs.

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MECHANISM OF INJURY:

Direct Injury:

These include five principal causes - motor vehicle accidents ,falls, sports injuries, direct blows or assaults and gunshot injuries.

Falls may be simple falls on his or her height, fall down stairs or slopes and fall from height.

The highest incidence is seen in motor vehicle accidents usually affecting the motor cyclists, pedestrians and automobile occupants.

Axial loading injuries:

Bone is viscoelastic, the rate of loading shifts the stress strain curve. Rapid axial loading absorbs and then at failure releases more energy. The released energy is imparted to the soft tissue. Part or the entire articular surface may be involved. The injury may be confined to an epiphyseal area just above the joint, it may involve the epiphysis and metaphysis or it may have an extension into the diaphysis. The precise direction of force and the position of the foot when it is applied lead to wide variation in fracture patterns.

CLASSIFICATION:

. Ruedi and Allgower[19] classification was the first in common use. Classification by Ruedi and Allgower is based on the severity of comminution and the displacement of the articular surface. Prognosis correlates with increasing grade.

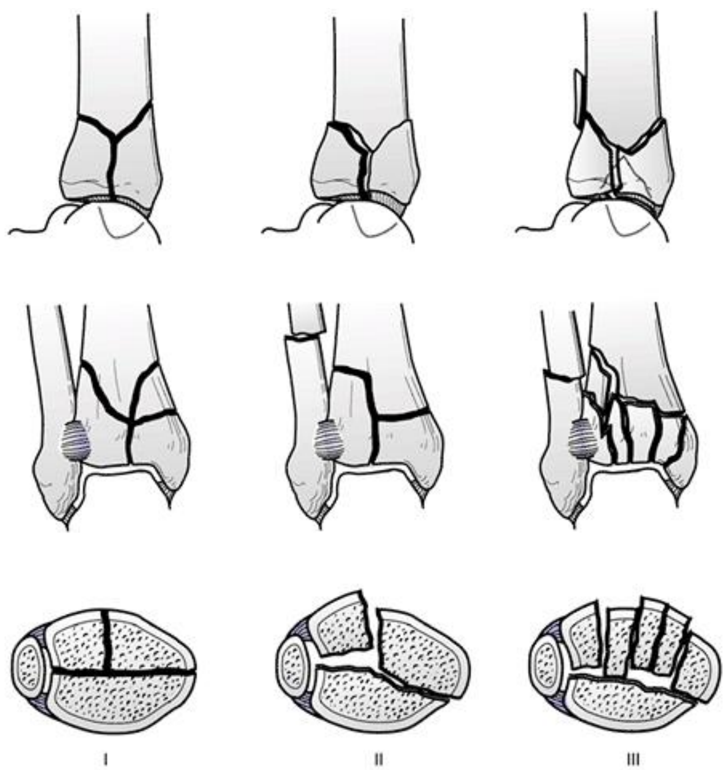


Figure 3 Ruedi Allgower classification

- **Type 1:** Nondisplaced cleavage fracture of the ankle joint

- **Type 2:** Displaced fracture with minimal impaction or comminution

- **Type 3:** Displaced fracture with significant articular comminution.

Another one the AO/OTA classification system[20], and this is now universally used for fractures of the distal tibia. In this system, distal tibial fractures are divided into the following categories: type A, nonarticuiar fractures; type B, partial articular fractures; and type C, total articular fractures.

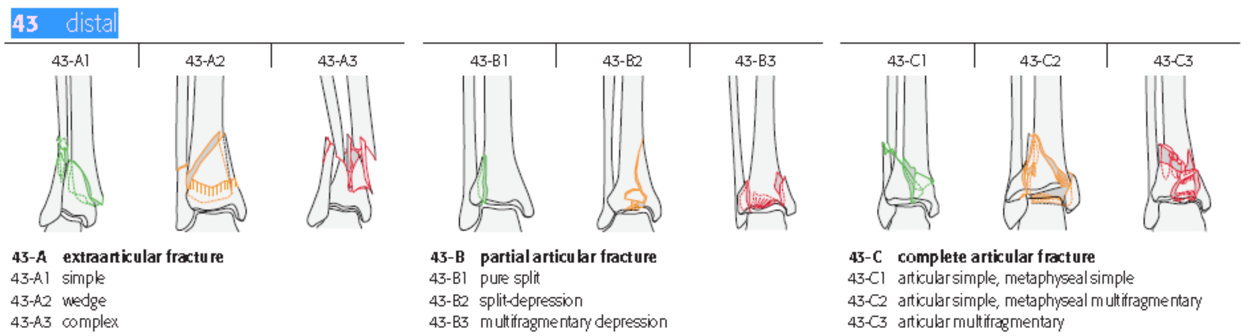


Figure 4: AO/OTA Classification of Distal Tibia Fractures

CLASSIFICATION OF OPEN FRACTURES[21]

Gustilo and Anderson in 1976 described a grading system that offered prognostic information about the outcome of infected fractures. In 1984, this system was modified. The modified classification is based on the size of the wound, amount of periosteal soft tissue damage, periosteal stripping, and vascular injury.

Gustilo and Anderson Classification of Open Fractures

Grade I:	Clean skin opening of <1 cm, usually from inside to outside; minimal muscle contusion; simple transverse or short oblique fractures
Grade II:	Laceration >1 cm long, with extensive soft tissue damage; minimal to moderate crushing component; simple transverse or short oblique fractures with minimal comminution
Grade III:	Extensive soft tissue damage, including muscles, skin, and neurovascular structures; often a high-energy injury with a severe crushing component
IIIA:	Extensive soft tissue laceration, adequate bone coverage; segmental fractures, gunshot injuries, minimal periosteal stripping

IIIB: Extensive soft tissue injury with periosteal stripping and bone exposure requiring soft tissue flap closure; usually associated with massive contamination

IIIC: Vascular injury requiring repair.

MANAGEMENT:

History:

Careful history of the mechanism of injury, the likelihood of associated injuries and the presence of co-morbid conditions that can affect treatment or bony union must be noted. The mechanism of injury provides an idea amount of energy imparted to the bone and soft tissue at the time of fracture, which is crucial for surgical planning and for advising the patient on prognosis. Mode of violence gives idea of soft tissue compromise. In open fractures, assessing the environment of injury occurred will guide antibiotic treatment[22].

Physical examination:

Distal tibia fractures are carefully examined for the extent of wound, amount of contamination present, Careful neurovascular examination of the extremity should follow documentation of the skin condition and presence of swelling. The associated injuries should be carefully looked for. Once life-threatening injuries have been ruled out, attention can be focused on the ankle injury. Deformity of the foot and ankle is often apparent. The neurological and vascular status of the foot must be evaluated. Splinting the ankle prevents further soft tissue trauma.

Open wounds are inspected to determine their extent and the amount of contamination. The condition of the skin should be carefully examined, including the amount of swelling and the presence of fracture blisters. Tense soft tissue swelling is frequently present and it is assessed by both inspection and palpation. The presence or absence of skin wrinkles has been recommended as one way to assess the degree of soft tissue swelling.41 The true extent of the soft tissue injury may not be evident initially, so the ankle must be frequently reassessed.

Fracture blisters are common and can be divided into two types ; clear fluid-filled and blood-filled blisters. Histologically, both types are separations in the dermal-epidermal junction, but blood-filled blisters are deeper and indicate more severe soft tissue injury. There have been more wound complications when incisions are made through blood-filled blisters. Local bruising and ecchymosis indicate a greater degree of deep soft tissue damage. Although compartment syndrome is unusual, it should be kept in mind, and the tenseness of the muscle compartments of the leg and foot should be assessed periodically. Compartment syndrome is more common in plafond fractures with diaphyseal extension[23].

Imaging

Standard radiographs are AP, lateral view of the ankle and mortise views. Repeat radiographs with the limb provisionally reduced provide more information about the fracture pattern and should routinely be obtained if the initial radiographs were taken with the talus widely displaced. Proximal extension of the fracture or suspicion of more proximal injury mandates that full-length tibia and fibula radiographs be obtained. Some surgeons find views of the contra lateral ankle helpful as a template for preoperative planning[6].

CT scan is an optimal adjunct to plain radiographs for further imaging of articular fractures of the lower extremity. It provides more information on fracture configuration and intraarticular extension than plain films and frequently alters the surgical plan.

TREATMENT OF OPEN FRACTURES:

The treatment of open fractures of tibia requires consideration of Soft tissue, initial injury and treatment modality selected for fracture stabilization. There are five keys for successful treatment. They are-

1. Radical debridement and copious irrigation.

2. Stabilization of fracture.

3. Antibiotic therapy.

4. Soft tissue coverage.

Functional rehabilitation and pre-emptive bone grafting in high energy trauma and bone loss patients is advisable.

Treatment recommendation of open fracture based on work of Gustilo & AO/ASIF group are[21]:

1. Treat all open fracture as an emergency.

2. Perform a thorough initial evaluation to evaluate other life threatening injuries,

3. Begin appropriate antibiotic therapy in the emergency room

4. Immediately debridement using copious irrigation and for types II and III, repeat the debridement in 24 hrs.

5. skeletal stabilisation.

6. Leave the wound open for 5-7 days.

7. Rehabilitate the involved extremity.

Surgical Debridement[24]

Debridement is a term to cover the following things - exploration of the wound, excision of devitalized tissue and removal of foreign material. The procedure includes the excision of devitalized structure layer by layer to the depth of the wound but respecting the integrity of important structure such as blood vessels, nerves and tendon. In extremity wounds debridement of contaminated and devitalized muscle often is of magnitude. Assessment of viability of damaged muscle is difficult but colour, consistency and the capacity of the muscle to bleed can be used as guidelines and will assist in determining viability. Muscle that is normal beefy red colour is viable. Viable muscle usually is firm in consistency, usually will contract when incised by a scalpel or touched by an electro cautery and will demonstrate its vascularity by bleeding from the cut edges.

The objectives of debridement (and irrigation) are:

1. The detection and removal of foreign material, especially organic foreign material.

2. The detection and removal of nonviable tissues.

3. The reduction of bacterial contamination.

4. The creation of a wound that can tolerate the residual bacterial contamination and heal without infection.

Irrigation should never be done under pressure, since foreign material can be forced into a tissue plane rather than floating freely out of the wounds. Irrigation and removal of all nonviable and contaminated tissue is the most essential manoeuvre of the procedure.

Proper use of a tourniquet in the debridement of open fractures is essential. It may be necessary to control severe haemorrhage encountered when a blood clot is removed from an unexpected major arterial injury. However, the tourniquet should not be inflated unless necessary to control bleeding, either for visualization or to limit blood loss, because the anoxia produced by the tourniquet interferes with evaluation of the viability of muscle.

After debridement, irrigation and reduction of fracture the question arises whether the wound should be closed with drainage or left open. Although no rule can be rigidly applied, the following recommendations arc offered. For Type1and 2, wound less than 12 hours old, loose closure of wound may be done when there is clean wound, if this is doubtful it is best to leave the wound open and plan a delayed closure in 4 to 6 days (Delayed primary closure) or later when wound conditions are favourable.

Relaxing incisions in the skin occasionally may be used to shift normal skin and subcutaneous tissue over such structures, but great care and planning are necessary to do this successfully.

Failure of wound healing from skin necrosis breakdown and secondary infection frequently result from attempts to close a wound or an incision under significant tension. Even when the wound has been converted to a clean wound, if its closure requires significant tension, it is best left open initially and managed with either delayed primary or secondary closure.

Pedicle grafts and split thickness grafts have a role in the initial management of the wounds of open fractures.

EXTERNAL FIXATORS

External fixation refers to the technique of fracture fixation in which the surgeon places pin or wire clusters in separate fracture segments and then connects the pins to external bars. The linkage maintains the fracture fragments in a desired spatial relationship[25].

The two basic types of external fixators include

1) The pin fixator and

2) The ring fixators

The marriage of the unilateral fixator to the tensioned ring leads to the introduction of hybrid external fixators to address the periarticular fractures.

Frame Components44

Pins:

The stability of the bone-pin interface determines the eventual outcome of the external fixation technique. External fixation pin options include thin wires, transfixation and half pins. Pin tip design, pin geometry and pin thread designs vary according to manufacturer. Stability with half pins is gained from purchase in the far cortex.

Transfixation pins (4 to 5mm) or full pins are usually centrally threaded and smooth on both ends. Thin wires (diameter of 1.5 to 2.0 mm) have become increasingly common with the use of hybrid and Ilizarov fixators. Usually two or three wires are used, with a ring. Stability is achieved by tensioning the wires, which results in increased rigidity. An olive wire is a thin wire with a bulb-like protuberance on one end that can be used for compression between fracture fragments or as an aid in fracture reduction.

Pin Clamps and Rings:

The second basic component used in an external fixator is the pin-bar clamp. The clamp serves to connect a pin or wire to a rod or ring. Simple clamps connect a single pin or wire to a rod, while modular clamps may connect several rods in a cluster. Some clamps have a ball-and-socket-type joint that allows more degrees of freedom in frame construction.

Rings were previously reserved for Ilizarov-type fixators but have become much more common with the use of hybrid external fixators. Rings are usually provided in one-half, five-eights, or full circumference. The diameter of the ring must be at least 2 to 3 cm larger than the limb at its maximum diameter. If too small a ring used, skin irritation may occur from edema during the course of treatment. If too large a diameter is used, the stability of the frame may be affected.

Connecting Rods:

The external fixator rings and clamps are attached to connecting components. These connectors can either be stainless steel, aluminium alloy, or carbon fiber and can have various cross-section geometries: circular, elliptical, square, or multiple-faced.

Frame Design:

The design of an external fixator frame must take into consideration both anatomic and biomechanical factors. The frame should be constructed to provide routes for repeat debridement, soft tissue flaps, secondary bone grafting, or delayed internal fixation. A tibial external fixator frame can be as simple as four pins with a single bar or as complex as a multi-ring fixator.

The advantage of a unilateral frame is simplicity. A severe traumatic limb injury can often be managed with a simple unilateral frame. A biplanar frame provides increased frame stiffness and improved control of bending or torsional moments when compared to a unilateral frame. The stiffness of relatively weak components can be increased by use of a biplanar frame.

Ring fixators allow multiplanar adjustments, but these fixators obstruct soft tissue access for both primary and secondary interventions.

The Hybrid External Fixator combines some of the advantages of the uniplanar and multiplanar external fixator. A hybrid allows rigid fixation of periarticular fractures with less complexity than a ring fixator. Fixators constructed with multiple levels of fixation (rings) in the periarticular fragment have been shown to be stiffer in all modes of testing, while augmentation of the ring to bar connection did not significantly affect stiffness of the frame.

Advantages of external fixators[21]:

1. The method provides rigid fixation

2. Compression, neutralization or fixed distraction of the fracture fragments is possible.

3. The direct surveillance of the limb is possible, including wound healing, neurovascular status and viability.

4. Associated treatment, e.g. wound dressing, skin grafting, bone grafting and irrigation, is feasible without disturbing the fracture reduction.

5. Immediate range of motions of the proximal and distal joints is allowed. Hence facilitates reduction of edema and nutrition of articular surfaces and retards fibrosis, joint stiffening, muscle atrophy and osteoporosis.

7. Pin insertion can be performed under local anaesthesia, if necessary.

9. Rigid fixation can be used in infected or non union of long bones. Rigid fixation of the bone fragment in infected fractures/

non unions is a critical factor in controlling and obliterating the infection

Disadvantages of external fixators[21]:

1. Pin tract infection is the most common complication, which can be prevented by following safe pin insertion technique and regular aseptic dressings. Mild infection to osteomyelites can occur with infected pin.

2. The frame may be cumbersome and the patient may not accept it for cosmetic reasons.

3. Refractor after frame removal may occur. Limb should be adequately immobilised and protected until the underlying bone can withstand stress.

Indications:

1. Severe types II and III compound fractures.

2. Fractures involving multiple bones.

3. Fractures requiring subsequent flaps or free vascularised grafts..

4. Certain fractures requiring distraction e.g. those associated with significant bone loss

5. Limb lengthening or deformity correction.

6. Arthrodesis.

7. Infected fractures or nonunion.

General principles and techniques of external skeletal fixation:

The treatment of the condition for which external fixator is planned must be considered first. Irrigation, debridement and reduction of the severe open fracture as primary treatment are essential.

A complete set of external skeletal fixator equipment must be available, regardless of the type of device preferred, before any attempt is made to treat a fracture. The surgeon should be thoroughly familiar with the equipment, preferably from previous experience or from practice with such equipment in a workshop or psychomotor skills laboratory. It is advisable to review the equipment and general technique applicable to a patient prior to application of the device. The desired pin placement and frame configuration should be decided before frame application is begun. Will the fracture configuration allow for compression; or will neutralization and/ or distraction be needed? Will half pins, transfixation pins, or a combination is needed? Pin location should be chosen so as to facilitate subsequent, dressing changes, skin grafts or other procedures, the patients comfort and convenience should also be considered.

The external fixator should be applied under general or spinal anaesthesia in the operating room under strict sterile conditions, ideally with image intensification fluoroscopic control. With an open fracture the soft tissue and bone fragments should be irrigated and debrided, and bone length, rotation and general alignment of the limb should be restored before the pins are inserted. Insertion of pins prior to fracture reduction will result in significant shifting of the soft tissues with impalement on the pins where they entered the skin. A well selected and adequately incised skin and fascia portal prior to fracture reduction may be under tension and can be impaled by a pin inserted prior to restoration of length and alignment of the limb. If the open wound permits, anatomic reduction of the fracture fragments under direct vision should be performed. Stabilization of unstable fragments by Kirschner wires or screws prior to insertion of the fixation pins and frames, if possible, is helpful. Reduction of the fracture should be as anatomic as possible. Since fracture healing with rigid external fixation is similar to that occurring with rigid internal fixation (i.e., largely endosteal), a good criterion for the acceptability of reduction is to determine whether the reduction would be acceptable if a rigid plate and screws were used for fixation. Large fracture gaps with little callus will be produced account for many of delayed unions and nonunions.

In such cases the use of supplemental internal fixation initially, e.g. : an interfragmentary screw or Kirschner wire, and early bone grafting will reduce these late complications. The Kirschner wires or screws may be removed, if desired, after the external fixator is applied and the fracture is rigidly immobilized. It is desirable to compress the fracture with the fixator if the fracture configuration is sufficiently stable.

Basic concepts[26]:

The safe soft tissue corridor for pin insertion is determined by the anatomy. In the distal third, the anterior tibial vessels are vulnerable along the lateral tibial cortex. Whenever possible, pin insertion should be limited to the subcutaneous areas of the tibia.

Care of the extremity following frame application:

The surgeon's responsibility does not end with treatment of the primary condition and application of the pins and frame. Very careful attention to the extremity is necessary to avoid problems common with external fixators. Important considerations include:

1. Elevation of the extremity to decrease edema. This may be accomplished by tying the fixator to the overhead frame on the bed with ropes or other materials.

2. Support of the dependent posterior soft tissue by dressings pads or slings. This technique also aids in preventing edema and haematoma in these tissues.

3. Support of the ankle by appropriate splinting to prevent contractures. This may be accomplished by slings, rubber hose, or specially constructed commercial splints that attach to the frame.

Heel cord tightness or contractures are common if this important aspect is ignored.

4. Exercise of the joints proximal and distal to the fixator.

5. Regular cleansing about the pin exit from the skin. Cleansing must be meticulous and done under sterile conditions. The crust of drainage or dried blood must be removed and the soft tissues pushed away from the pins, breaking any seal about the pins. The use of antibiotic ointment about the pin-skin interface is optional. The pin-skin junction is usually not bandaged unless required by the dressing for associated soft tissue injuries are expected. The incidence of pin tract problems slowly increases the longer the fixator remains in place.

Observation for changing skin tension about the pins as the swelling subsides. An initially adequate skin portal may come under tension as the skin shifts when swelling subsides. If this occurs the skin and fascia about the base of the pins should be incised under local anaesthesia. Failure to relieve skin impaled about the base of the pin will result in increasing pain and potential pin tract problems. Assume that painful pin tracts are infected until proved otherwise. If a pin tract becomes red and painful, exercise of the adjacent joints should be discontinued and the skin tension about the pins checked. If the skin is tense it should be incised; if not, stopping the exercises tor a few days may allow toe reaction to subside. If the pin exit remains painful and red, it should be incised and drained under local anaesthesia. If the pain and drainage persist, the pin is loose and should be removed. Local or systemic antibiotic therapy may be used but will not solve a significant pin tract problem alone. Individualization of the time the fixator remains in place, as determined by the nature of the primary condition, the condition of the soft tissues, etc. If used for severe, open Gustilo type II or III fractures, the fixator should remain in place until good stable wound and skin coverage and tissue stability has been achieved, associated soft tissue procedures are complete. The time varies from two to three weeks in some situations and from 12 to 14 weeks in others.

As a general rule, the fixator used in fracture management should be removed when the fracture has been converted to a closed situation internal fixation or cast techniques can be applied.

Complications[21]:

Neurovascular Impalement:

The surgeon must be familiar with the cross-sectional anatomy of the limb and with the relatively safe zones and danger zones for pin insertion.

Muscle or Tendon Impalement:

Pins inserted through tendons or muscles restrain them from their normal excursion and can lead to tendon rupture or muscle fibrosis.

Delayed Union:

The rigid external fixator construct can "unload" the fracture site, thus preventing compression and hence union.

Pin tract infection:

It may vary from mild superficial infection to osteomyelites, Dahl graded them from grade 1 to grade 5 depending on the degree of infection.

Refracture :

Union due to the rigid fixation is largely endosteal, with very little peripheral callus formation.. Refracture after fixator removal is possible, unless crutches, supplemental casts, or supports adequately protect the limb.

Limitation of Future Alternatives:

Open reduction become difficult if pin tracks become infected.

HYBRID EXTERNAL FIXATOR

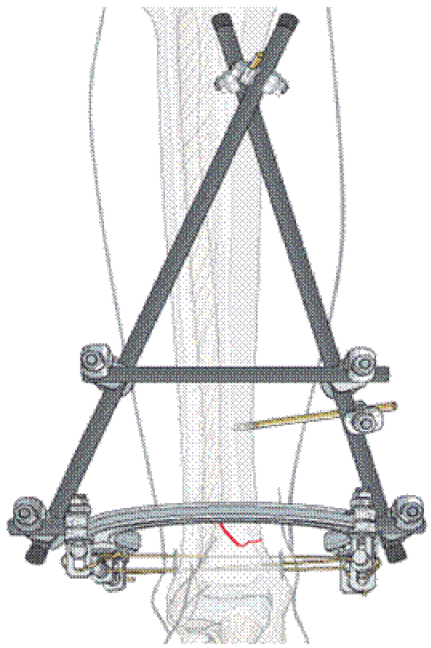


Figure 5 Distal tibial hybrid fixator

Hybrid external fixators consist of tensioned wires in the distal fragment of the tibia connected to half pins placed in the diaphysis. These devices preserve soft tissues than do plating devices. The tensioned wires, are used as interfragmentary screws, can be used for reduction and fixation of articular fragments. Keeping the ring construct to the same side of the joint has potential advantages and disadvantages.

The joints are not immobilized, hence stiffness is less. In fractures with extreme articular comminution, the wires may not provide adequate fixation. Hybrid fixators are most appropriate for AO types A, CI and C2 fractures.

Complications of Distal Tibia fractures[22]

Malunion:

Malunion is common after highly comminuted pilon fractures. Angular malalignment is also possible. Accurate intraoperative alignment before tightening fixator is must. It is essential to follow the patient closely to see that alignment is maintained until the fracture is healed as loss of reduction can occur during follow up.

Nonunion and Delayed Union:

The incidence of nonunion and delayed union appears to be about 5% regardless of the treatment method in distal tibial fractures.

Infection and Wound Dehiscence:

More common following plating, open surgery should be deferred until wrinkle sign appears.

Stiffness of Ankle:

Decreased Range of motion of ankle joint is common after tibial pilon fractures if the ankle is immobilised with casts or patient not following physiotherapy regimen.

Secondary Arthritis:

Articular cartilage damage & poor quality of reduction contributes to the development of arthritis. Other contributing factors are avascular necrosis of subchondral bone fragments and infection.

MATERIALS & METHODS

A prospective study was conducted in Government Royapettah Hospital, Chennai from June 2011 to June 2013. The Study included a series of twenty five patients with distal tibial fractures. Prior approval from the Institutional Ethical Committee was obtained. All patients were explained clearly about the study and an informed consent was obtained from each of them.

Inclusion Criteria

- Patients in the age group of above 18 years
- Distal tibial fractures involving distal 5cm of tibia – AO type A ,B and C
- Patients with open & closed fractures

Exclusion Criteria

- Skeletal immaturity,
- Patients not willing for External Fixator,

Age distribution:

The age of the patients ranged from 21-80 years with the fracture being most

common in the 5th decade. The mean age was **43.6** years.

Table 1: Age Distribution

Age in years	Patients	Percentage
21-30	02	08 %
31-40	06	24 %
41-50	09	36 %
51-60	05	20 %
>60	03	12 %

Sex Distribution:

Out of 25 patients, 20 (80%) patients were males and 05 (20%) patients were females, showing male preponderance because of travelling and outdoor works.

Table 2 Sex Distribution

Sex	Patients	Percentage
Male	20	80 %
Female	05	20 %

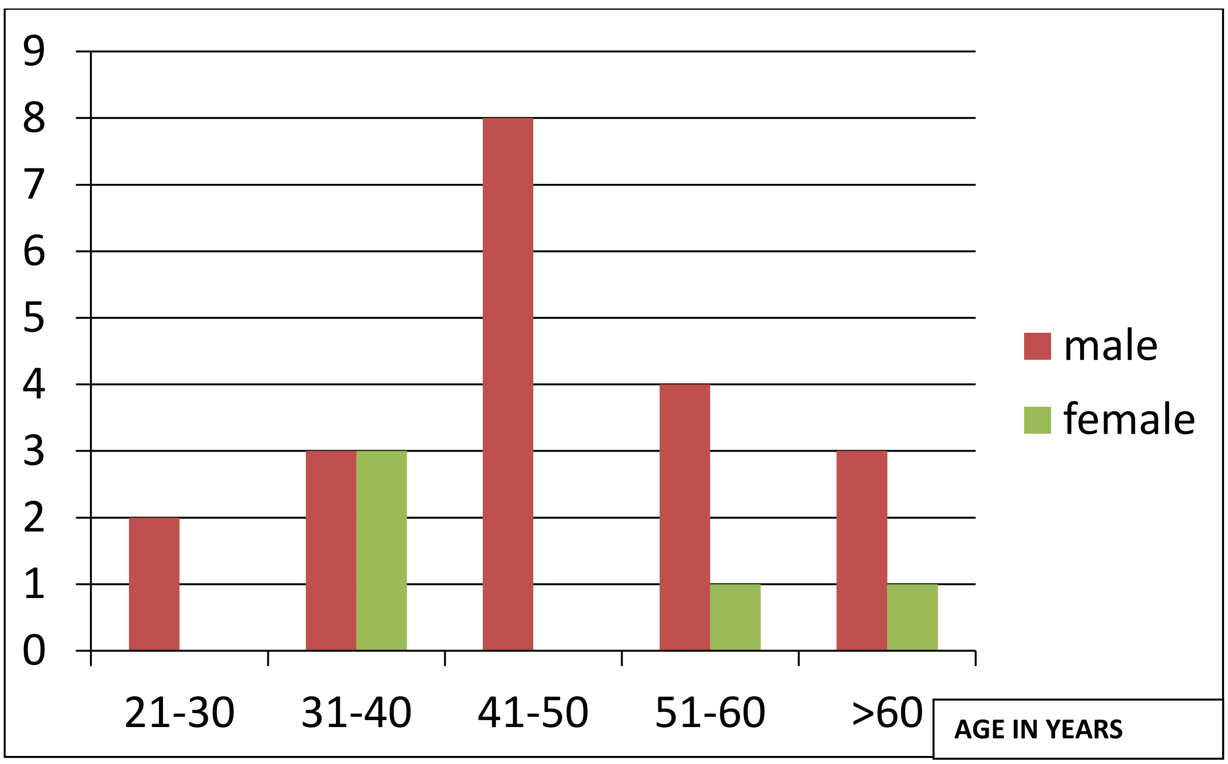


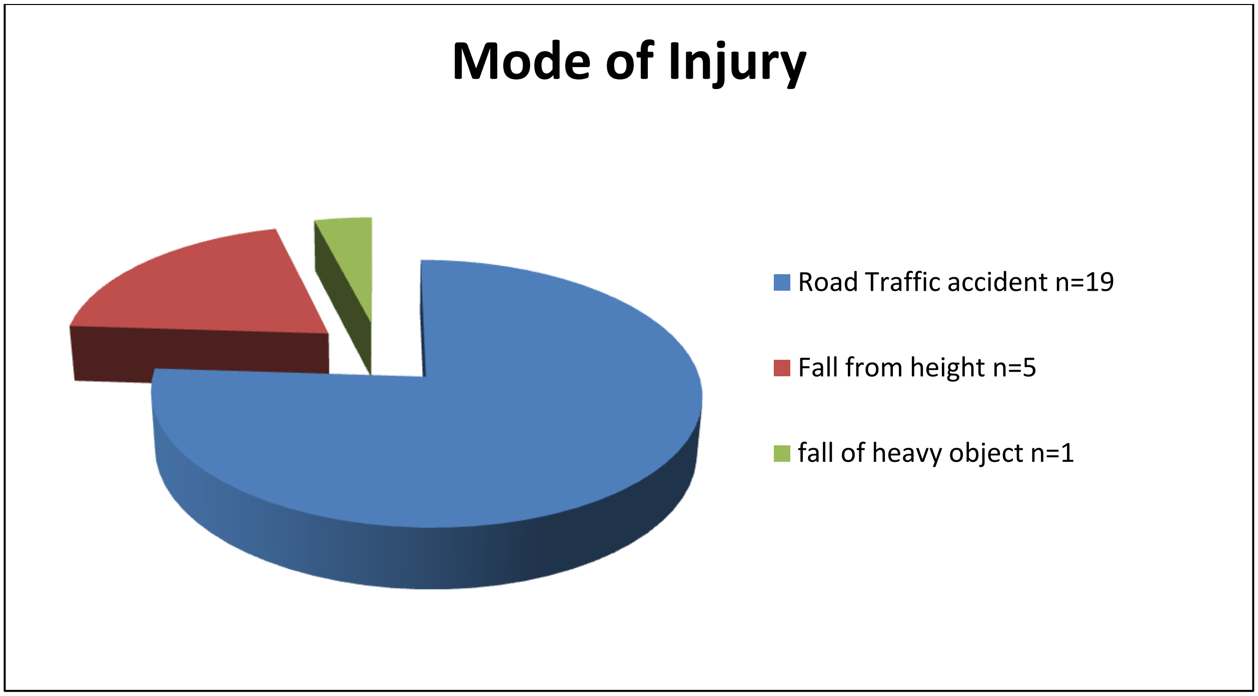
Figure 6 AGE & SEX DISTRIBUTION

Mode of injury:

In our study, 19 (76%) patients sustained injury following motor vehicle accident and 5(20%) cases had injury following fall. 1 patient (4%) had a history of fall of heavy object over leg.

Table 3 Mode of Injury:

Mode of Injury	**Patients**	**Percentage**
Road traffic accident	19	76 %
Fall from height	05	20 %
Fall of heavy object	01	04 %

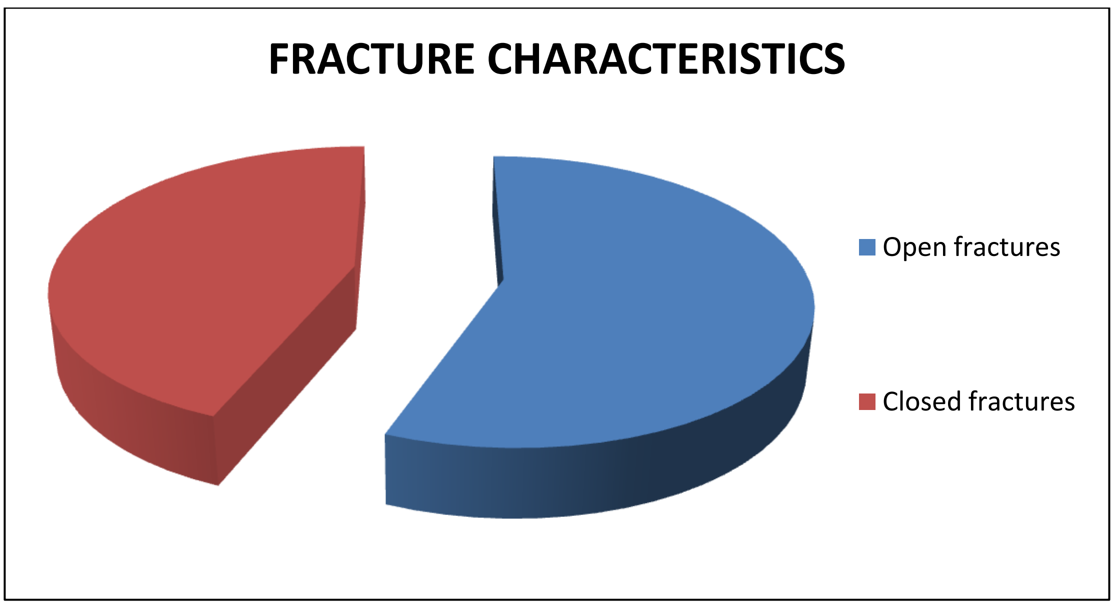


Fracture Characteristics:

Out of the 25 cases, 14 (56%) cases were open fractures and 11(44%) cases were closed fractures.

Table 4 Fracture characteristics

Type	Numbers	Percentage
Open	14	56 %
Closed	11	44 %



Open fractures:

Classification of the 14 cases of open fractures based on Gustilo Anderson

Classification of open fractures gives 7 (50 %) were type I compound, 5 (36 %) were of type II compound, 2(04 %) were type III**.**

Table 5 Classification of open fractures

Gustilo & Anderson classification	**Patients**	**Percentage amongst open fractures**
Type I	07	50 %
Type II	05	36 %
Type III	02	04 %

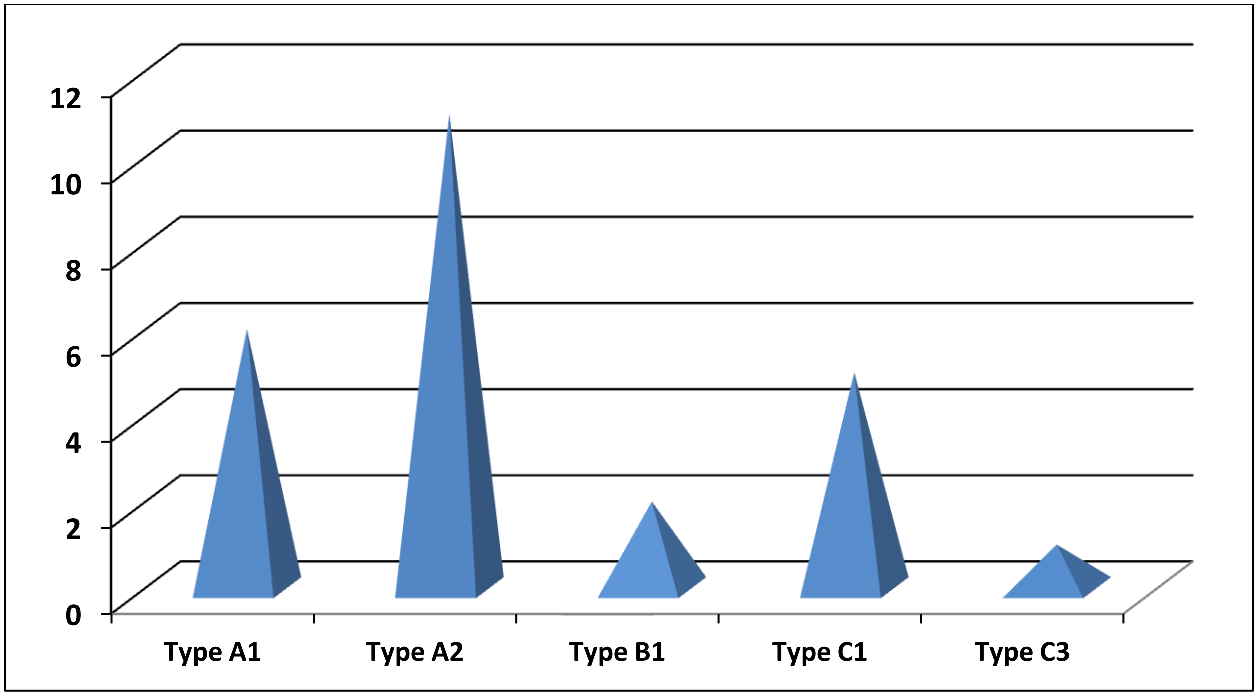


Figure 7 GRADING OPEN FRACTURE- GUSTILO ANDERSON CLASSIFICATION

Fracture Pattern:

The fracture pattern was classified based on AO/OTA classification for fractures of distal tibia. Among the 25 cases studied, 6 (33%) cases were Al, 11(48%) were A3, 2 patients were Type B, 5(14%) were C1 and 1 (5%) case was C3 type of fracture.

Table 6 Fracture pattern

AO/OTA	Patients	Percentage
Type A1	6	24 %
Type A3	11	44 %
Type B 1	2	08 %
Type C1	5	20 %
Type C3	1	04 %

Associated Injuries:

All 25 cases studied had an associated fracture of the fibula. One patient had a fracture lower end of radius on the ipsilateral side of the injury which was treated by closed reduction and ligamentotaxis with external fixator application.

All patients were evaluated in the emergency room as per ATLS protocol.

Careful history taking and methodical examination was done. Once the patient is stable, radiographic evaluation of the affected leg and ankle was made.

MANAGEMENT OF OPEN FRACTURES:

Open fractures (n=16) were graded as per Gustilo and Anderson classification system for open fractures, Injection Tetanus toxoid and intravenous antibiotics (Third generation cephalosporin &

Aminoglycosides) were given. After obtaining initial radiographs all patients with type I and II open fractures were given wound wash with copious normal saline and in some cases with hydrogen peroxide if contamination with dirt and grease present. It is followed by painting the wound with Povidone iodine all around and primary wound closure was done. Limb was then immobilised with a posterior slab and elevated. All Type III open fractures were debrided immediately, all devitalised tissues were removed, copious wound wash was given and posterior slab was applied till definitive hybrid fixation was done. In two patients initial joint spanning fixator was applied and kept for about 5 days till application of Hybrid fixator after management of co-morbid conditions. Three patients with open fractures presented to us with plaster with wound healed well, they were grouped under open fractures in the study. All other open fractures were operated in the next day in elective OT and Hybrid fixator application done under Image intensifier control within 48 hours.

MANAGEMENT OF CLOSED FRACTURES:

Closed fractures (n=11) were examined for skin condition, contusion, swelling, deformity, local temperature and parasthesia were noted. Fractures were classified as per AO/OTA classification system, they were initially treated by manual traction and posterior Above Knee slab was applied and limb was kept on limb elevation for soft tissue healing. Closed fractures with good skin condition were operated at an average of 4.1 days from the day of injury (range 1 day to 8 days)

Interval between injury and surgery:

Mean time interval between injury and the surgical intervention is 4.1 days (Range 1 day to 8 days) and for open fractures was 24.9

hrs (range 8 hrs to 72 hrs). Certain delay in treating open fractures was due to poor general condition of the patients, associated co-morbidities and alcohol intoxication at the time of presentation.

SURGICAL TECHNIQUE:

All patients who satisfy inclusion criteria were admitted and preoperative work up was done. All patients were operated in elective OT under anaesthesia and fluoroscopic imaging.

Preoperative work-up:

Elaborate history regarding co-morbid conditions, drug allergies and previous treatments were taken in addition to details regarding the nature of violence and contaminants in the place of injury. Local skin condition, tendon functioning, neurovascular status were documented. ECG & chest X-ray were taken. Routine blood investigations TC, DC, ESR, Hb, Urea, Sugar, Creatinine were done. Screening for HIV and HbsAg was done in all patients. Patients were explained of the procedure and written consent was obtained. The fractured limb was prepared beforehand and instruments were checked and sterilised on the day before surgery.

Mode of Anaesthesia: All patients were evaluated and preoperative assessment was done. Most patients were operated under Regional anaesthesia (lumbar subarachnoid block) except for one patient with distal radius fracture for whom Distal radius external fixator application and ligamentotaxis was done simultaneously in same sitting under General anaesthesia. Pre op test dose of all Anaesthetic and antibiotic drugs were given.

Implants & Instruments used:

Hybrid fixator construct used in the study was made of a single ring external fixator assembled with tensioned transfixator wires in distal fragment. The proximal fragment of the fracture was held in position by tubular external fixator and Schanz pins. The implant requirements were

Figure 8 Implants and instruments required for Hybrid fixator

1. 160 mm Ilizarov Half rings,
2. Bayonet point Ilizarov wires 1.5mm & 1.8mm × 300mm,
3. Wire fixation bolts side & centre slotted,
4. Nuts 6mm
5. Connection Bolts 10mm, 20mm
6. Rancho cubes 1-4 holed
7. Twisted connecting plates
8. Schanz pins 4.5mm
9. AO rods 8mm diameter
10. 3.5 mm drill bits & drill sleeves
11. Hand drill/ power drill
12. T handle
13. Wire bender and cutter
14. Tapered half pins 150mm length, 30mm thread length

15. Connection plates with threaded ends (male post)

16. Tubular rods

17. General surgical instruments.

OPERATIVE PROCEDURE:

Position: Supine on operating table with affected limb elevated on pillows underneath.

Procedure: Under fluoroscopic control, fracture is manipulated and provisional reduction was checked. Fibular fixation is done in cases where level of fibula fracture is at or below the level of syndesmosis. Fixation of fibula is done after prior simultaneous reduction of tibia and fibula. Fibular fixation was done with open reduction and plating or intramedullary K-wires. Operative steps for tibial fixation are as follows

RESTORING PERIARTICULAR FRAGMENT:

1. Periarticular fragment was reduced with pointed reduction forceps through mini incision or by open reduction and was secured by three Ilizarov wires. The wires were pushed manually then drilled across the cortices. Olive wires were used when interfragmentary compression was aimed or else Bayonet tipped wires is used.
2. Wire placement was through safe corridors for distal tibia avoiding neurovascular structures.
3. First wire is passed parallel to the joint from posterolateral to anteromedial transfixing the fibula. Appropriate size Ilizarov ring is used maintaining at least 3 cm distance from leg to ring in all sides.

Figure 9 Image intensifier guided olive wire insertion

4. Other two wires passed from posteromedial to anterolateral and direct medial to lateral at an angle of 30 to 60 degree from each other.
5. Internal fixation with screws was performed if necessary before passage of wires.

6. Wires were checked for any tendon impalement and revised. The wires were fixed to the rings using slotted wire fixation bolts and tensioned.
7. Skin tethering around the entry points were noted and released appropriately with smaller incisions.

SECURING DIAPHYSEAL FRAGMENT:

1. The AO tibial external fixator pins were used for holding diaphyseal fragment. Two to three Schanz pins were placed about 3cm apart in anteromedial aspect of tibia perpendicular to the tibia.
2. Generous skin incisions were made, skin, fascia were incised, with drill sleeve 3.2 mm drill bit was used to drill both cortices. Schanz pins were introduced with T handle and bicortical purchase was obtained.
3. All pins were applied in sagittal plane and connected to each other by AO clamp and AO rods.

FRACTURE REDUCTION & FRAME ASSEMBLY:

1. Fracture reduction was applied using ligamentotaxis and AP/ Lateral angulations in distal fragment and verified with image intensifier.

2. The AO rod is connected to the ring by twisted connecting plate or Male post with AO Clamp modified and connected to each other
3. All nuts and bolts were tightened.
4. Additional AO rods were placed between proximal fragment and the ring construct for extra stability if required.
5. Compound fractures were debrided and wound closed intraop.

Figure 10 Hybrid Construct with AO rod connected to Ring with Male post and AO clamp

Duration of Surgery:

The duration of surgery ranged from 40 to 110 minutes averaging **83minutes**. The operating time reduced with fractures having lesser grade as per AO/OTA classification increasing experience of the operating surgeons in fixing these fractures.

Minimal internal fixation:

In one of the patients with type 3 fracture, we had stabilized the coronal fracture of the distal tibia with intra articular extension using compression screws applied percutaneously.

POST OPERATIVE REGIMEN:

1. Active mobilization of the ankle, knee and non-weight bearing walking using standard walking frame was done

from the second post operative day under the supervision of a physiotherapist.

2. Intravenous antibiotic regimen was continued for 5-7 days (12-14 days in compound fractures) after the surgery. Another 5 days of oral antibiotics were advised. Regular cleansing of the pin exit points was done.

3. Patients were encouraged to do non weight bearing walking.

Figure 11 HYBRID EXTERNAL FIXATOR ASSEMBLY

FOLLOW UP:

Patients were followed up once in three weeks until fracture union and once in three months after that. The fracture was said to united when there was bridging callus at the fracture site at least in three cortices in the anteroposterior and lateral views. Trabeculations extending across the fracture site was also taken into consideration.

Fixator removal was done after radiological evidence of union and a period of pain free partial weight bearing by the patient. Before fixator removal union was confirmed by image intensifier in continuous mode. After fixator removal, posterior slab was given for a period of two weeks, when all the pin tracts healed well, patients were allowed for full weight bearing with ankle splint. Ankle splint was discontinued once patient has regained pain free range of movements.

We followed Ovadia & Beals objective and subjective scoring system for analysing the results.

Figure 12 OVADIA & BEALS OBJECTIVE SCORING CRITERIA

S.no	Parameter	Excellent	Good	Fair	Poor
1	**ROM**	>75 %	50 -75%	25-50%	<25%
2	**T-T alignment**	In axis	In axis	<5*	>5*
3	**Tibial shortening**	Absent	Absent	<1cm	>1cm
4	**Chronic edema**	Absent	Slight	Moderate	Severe
5	**Pronation supination**	Normal	Normal	Slightly reduced	Very reduced
6	**Fixed deformities**	Absent	Absent	Absent	Present

Figure 13 OVADIA & BEALS SUBJECTIVE SCORING CRITERIA

S.no	Parameter	Excellent	Good	Fair	Poor
1	**Pain**	Absent	Slight	Moderate	Severe
2	**Return to work**	Same job	Same job	Different job	Impossible
3	**Recreational activity**	Unchanged	Slightly changed	Greatly changed	Impossible
4	**Limitations to walking**	Absent	Absent	Present	Present
5	**Analgesics**	Not Necessary	Not necessary	Necessary	Opiates
6	**Limping**	Absent	Absent	Occasional	Present

ANALYSIS & RESULTS

The present study consists of 25 cases of distal tibia fractures. All the patients were followed up periodically and mean follow up was 12.5 months.

All patients were evaluated for bony union, deformity, infection and range of motion of adjacent joints. Outcomes were analysed using Ovadia and Beals outcome criteria.

Duration of fracture union:

The fractures united with an average of **21.12 weeks** (Range =15-30 weeks). There were three cases of delayed union which united with bone grafting. There was one non-union.

Table 7 Ovadia & Beals Objective evaluation

Result	Patients	Percentage
Excellent	08	32 %
Good	11	44 %
Fair	05	20 %
Poor	01	04 %

Table 8 Ovadia & Beals Subjective evaluation

Result	Patients	Percentage
Excellent	10	40 %
Good	10	40 %
Fair	04	16 %
Poor	01	04 %

COMPLICATIONS:

Intra operative complications:

There were no cases of intraoperative complications.

Post operative complications:

1. **Pin tract infections**:

Sixteen (64%) of the patients developed superficial pin tract infections, which were treated with daily dressings, antibiotic injection at pin tract and appropriate oral or intravenous antibiotics after pus culture and sensitivity. All these infections subsided with outpatient treatment expect for two (08%) patients who required admission and intravenous antibiotics. Motivation of patients and attenders reduced the occurrence of pin tract infection.

2. **Joint stiffness**:

We had 6 patients (24%) with ankle stiffness. This was probably due to the noncompliance of the patient to the advised physiotherapy regimen and due to the presence of intra-articular extension in these fractures.

3. **Delayed union**:

Three patients with open fractures had delayed union which were treated with secondary bone grafting.

4. **Malunions & Non union**:

One case of valgus malunion (4%) was present in a patient where fibular length was not maintained with internal fixation. One patient (4%) had non union which was planned for plate osteosynthesis and patient refused second surgery.

5. **Tendon impalement**:

One patient had tethering of extensor tendon of great toe. Patient refuses intervention by plastic surgeons as he is asymptomatic.

Two patients had loss of reduction during follow up which were managed with tightening of the construct.

None of the patient had osteomyelites,

septic arthritis or DVT

Table 9 Complications following Hybrid fixator for distal tibia fractures

Complication	Patient	Percentage
Pin tract infection	16	64 %
Joint stiffness	6	24%
Malunion	1	04%
Non union	1	04%
Delayed union	3	12%
Tendon impalement	1	04%

ILLUSTRATIVE CASES

CASE 1

21 Years male,

Grade III open fracture,

AO 43 Type A1 simple extraarticular distal tibia fracture,

Hybrid fixator application with primary closure of wound done 8hrs after injury,

Post operative period uneventful

Bony union at 28 weeks.

Ovadia & Beals evaluation score: Excellent

CASE 2

47 male

Closed fracture

AO 43 A 3 distal tibia fracture

Hybrid external fixator with intramedullary K wire of Fibula done.

Pin tract infection seen treated by oral antibiotics.

Bony union at 24 weeks

Ovadia & Beals evaluation score: excellent

CASE 3

32 M

Grade 1 open fracture

AO Type C1 simple articular, simple metaphyseal

Hybrid fixator application with Fibular plating done 16 hrs after injury

Bony union at 16 weeks.

Ovadia & Beals evaluation score: good

CASE 4

59 M

Type II open fracture

AO 43 A 2 metaphyseal wedge

Hybrid fixator applied after 36 hrs

Pin tract infection (+) treated by iv Antibiotics

Bony union at 21 weeks

Ovadia & Beals evaluation score: good

CASE 5:

39M

Grade II open fracture

AO Type C1 articular simple, Metaphyseal simple

Hybrid external fixator application done

Bony union at 23 weeks

Ovadia & Beals evaluation score: Good

CASE 6:

44m

Grade II open fracture

AO Type A1 metaphyseal simple

Hybrid fixator application done

Bony union at 18 months

Ovadia and Beals evaluation score: Excellent

Case 1

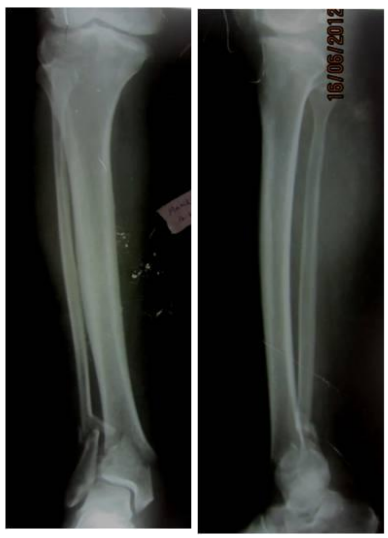
Pre op

Immediate Post op

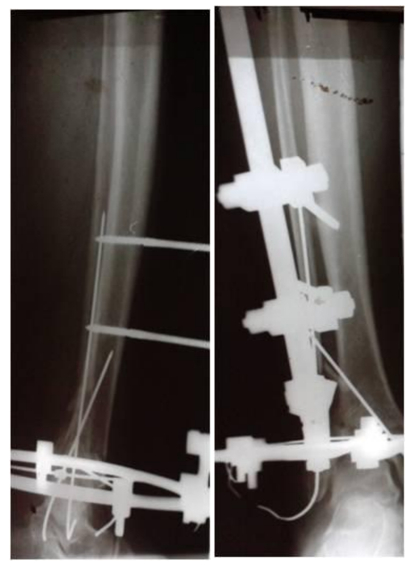
5 month post op

Case 2

Pre op



Post OP

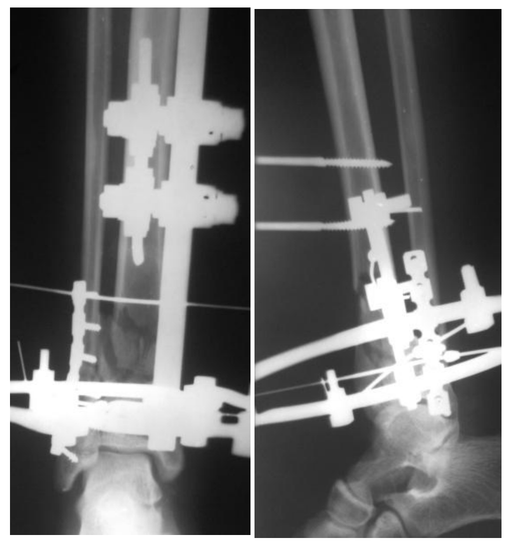


5 months post op

Case 3

Pre OP

Post Op



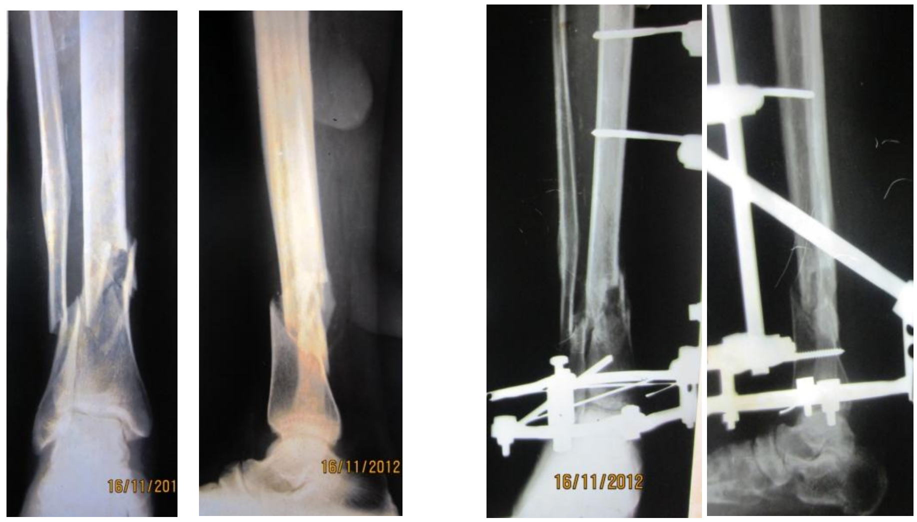
5months postup

Clinical follow up

Case 4

Pre op

Post Op



7 months post op


16/11
16/11/2012

Case 5

Pre op

Post op

4 months followup

Case 6

6 months Post op

COMPLICATIONS

Pin tract infection

Ankle stiffness

EHL tendon impalement

Valgus Malunion

DISCUSSION

Distal tibia fractures are one of the most difficult fractures to treat. The soft tissue status, the degree of comminution and articular damage sustained determines the final results. The aim of surgery is to obtain anatomic reduction of the articular surface and providing stability. This should be accomplished using procedures that decrease osseous and soft tissue de-vascularization. Hybrid external fixator is one such modality.

The present study was under taken to determine the efficacy of the Hybrid external Fixator in treatment of the fractures of the distal tibia. We evaluated our results and various factors are discussed.

Our study revealed the average age of patients with such injuries to be **43.6** years (Range 21to 80 years) which is comparable to that of other studies.

In our study, the male preponderance were high 80% compared to the study by Barbieri et al[11], which was 59% .12% of our patients were above 60 years all of them showed good results, as tensioned wires can provide stable fixation even in osteoporotic bones[28].

Gaudinez[12] et al observed 93% high energy fractures in his study. Ovadia and Beals[3] could attribute only 46% of such injuries to be of high energy; however our present study correlates with the study conducted by Agarwal et al[40] who had 87 % patients with high energy injuries. In our study road traffic accident (80%) was the predominant mode of violence.

Our study had 64% open injuries. This is comparable to studies conducted by Guadinez et al. Ovadia and Beals[3] reported 20% open injuries, Barbieri et al had 30% of open injuries in their series. Clinical outcome of patients with open fractures were fair to good mainly because of persistent mild swelling around the ankle and delayed union time.

Study by Barbieri et al showed 9% Al, 9% A2, 10% A3, 16% C1, 32% C2 and 24% C3. Kevin et al also had similar fracture type in their study. We had 68% patients with extraarticular fractures (Type A) who showed good to excellent results, while patients with Type C fractures showed fair to good results mainly due to ankle stiffness, low grade pain while walking on uneven surfaces and presence of chronic edema.

All patients had fracture of fibula; Fibular length restoration was done in closed fractures where the fracture level is at or below the level of syndesmosis as suggested by several studies[33]. In open fractures where the fibular fixation was not possible due to wound condition the final results showed malunion and change in the tibiotalar axis.

Time of union:

The average time for fracture union in various studies conducted using various was 13-25 weeks. Our study had an average fracture union of 21.12 weeks which were comparable with other studies conducted using the hybrid external fixator. Barbieri et al had an average fracture union of 16 weeks and

Gaudinez el al had an average of 13 weeks for the distal tibia. In our study type B fractures had prolonged time for union due to metaphyseal bone defect which requires primary bone graft. The delay in union time may be due to more number of compound fractures and hence not using bone grafting primarily.

Figure 14 COMPARISON OF TIME TAKEN FOR UNION

Study	**Time to union in weeks**
Barberi et al	16
Tornetta[35] et al	17
Guandinez et al	13
Anglen[28] et al	20
Mayil Natarajan[29]	28
Present study	**21.2**

Guadinez et al in their study of 14 distal tibial fractures treated by hybrid external fixation had 1 patient (14%) with varus mal-alignment and 8 patients (57%) with pin tract infections.

In Barbieri et al's study of 37 distal tibial fractures managed by hybrid external fixator had 5 patients(14%) with pin tract infections, 3 patients (9%) with non union, 3 patients(9%) had loss of reduction requiring re alignment and 5 patients(15%) had post traumatic tibio-talar arthritis.

In the present study, there were 16 cases (64%) of pin tract infections which healed with regular dressings and antibiotics, 06 (24%) cases of ankle stiffness, 01 case (04%) of valgus malunions, 01 case of tendon impalement (4%) and one case (4%) of non union. Pin tract infections were seen repeatedly in patients who were not practising to pin tract care.

In a study that established open reduction with plate and screw fixation as the standard, Ruedi and Allgower achieved 74% acceptable results in 84 patients. Mast et al[35] reported 78%

satisfactory results in 37 patients with a minimum follow up interval of 6 months. Less dramatic results were reported by a variety of authors when the plafond fractures studied included larger numbers of high energy injuries. Bourne et al[2] studied 42 patients with tibial plafond fractures, 62% of whom were victims of high-energy trauma. Of the 16 Ruedi type III fractures treated by open reduction and internal fixation, only 44% had satisfactory result. The majority of these fractures were complicated by nonunion (25%), infection (13%) and arthrodesis (32%).

Collinge et al[37] in a study of high energy distal metaphyseal fractures managed by minimally invasive plating ,average fracture healing time was 35 weeks with acceptable alignment restored in all except 1 case. Two patients (7%) had loss of fixation and 9 (35%) required secondary surgeries to achieve union.

Bone et al[7] reported in his series of distal tibia fractures treated using limited open reduction and internal fixation of the articular surface followed by neutralization of the fracture with an external fixator placed across the ankle joint. All the fractures healed and only 2 patients (10%) had poor clinical results. There were minimal complications with 2 pin tract infections (20%), no deep infections, and no skin sloughing.

Bonar and Marsh[8] reported on use of hinged transarticular external fixator to treat pilon fractures. Post operative complications were minimal with no cases of superficial or deep wound dehiscence. There were 5 cases of pin tract infection. There was no osteomyelites. The results were described as good in 69%, fair in 20% and poor in 11%.

Using the technique of hybrid external fixator, Tornetta et al[33] accomplished 69% good results in the high energy injuries and major complications were avoided. There was one deep infection, one superficial infection, one malunion and three pin tract infections. Barbieri et al achieved 67% good results using the hybrid external fixator. There were three cases of osteomyelites, one skin sloughing and five pin tract infections. Three patients had a loss of reduction and required frame revision. Gaudinez et al based their study on distal tibia fractures, using the scale by Ovadia and Beals, they had 64% patients having good to excellent objective results, and 71% patients had good to excellent subjective results. Complications included superficial pin tract infections in 3 patients.

Zeman[39] et al in a study of using hybrid external fixators for periarticular fractures of the tibia obtained 5 excellent (26%), 6 very good (32%), 5 satisfactory (26%) and 3 poor results (16%).

Table 10 COMPARISION OF RESULTS BASED ON OVADIA AND BEALS CRITERIA

	EXCELLENT	GOOD	FAIR	POOR
Aggarwal et al	26	50	14%	10%
Zeman et al	26 %	32%	26%	16%
Mayil Natarajan et al	50%	20%	15%	15%
Present study	**32%**	**44%**	**20%**	**04%**

Aggarwal et al[40] in their study of hybrid external fixation of high energy peri articular fractures of the tibia had results that were good to excellent in 30(86%), fair in 2(6%)and poor in 3(8%).

In the present study we had 25 distal metaphyseal fractures managed by hybrid external fixator. All the fractures except one united at an average of **21.12 weeks.** There were 17 good to excellent results and 5 fair results and 1 poor result in our study. There were 16 cases of pin tract infection (64%), 6 cases of ankle stiffness (24%), 1(4%) valgus malunion and 1(4%) case of non union.

Advantages with use of Hybrid fixator:

- Hybrid fixator can maintain length and alignment while spanning the comminuted region; it allows access to any open wound or compromised soft tissue.
- The use of olive wires from opposite directions helps in achieving interfragmentary compression and articular congruity.

Limitations of hybrid fixation:

- Difficulty in radiographic visualization of the articular surface with the fixator in place
- An inability to dynamize the construct
- Hybrid fixators, unlike well-constructed multi-ring fixators, do not provide enough stability for early weight bearing.

The present case series though small in number shows that Hybrid external fixator is an effective treatment method for distal tibial fractures especially open fractures in terms of union time and complications rate which is comparable to other studies.

CONCLUSION

- Hybrid fixation for distal tibia fracture provide fracture fixation without further damaging soft tissues,
- Hybrid fixator is an effective method for Open fractures of distal tibia.
- It provides good access to soft tissue and wound care.
- Simultaneous fibular fixation prevents malunion.
- Hybrid external fixation is a viable option in the management of distal tibial fractures especially fractures with soft tissue compromise and open fractures.

BIBILIOGRAPHY

1. Ruedi TP, Allgower M. The operative treatment of intra articular fractures of the lower end of tibia. Clin Orthop 1979; 138:105-110.

2. Bourne R, Rorabeck C, Macnab J. Intra-articular fractures of the distal tibia: The pilon fracture. J Trauma 1983; 23:591-596.

3. Ovadia DN, Beals RK. Fractures of the tibial plafond.J Bone Joint Surg Am.1986;68:543-551

4. Ovadia DN, Beals RK. Fractures of the tibial plafond.J Bone Joint Surg Am.1986;68:543-551 .

5. Wyrsch B, McFerran MA, McAndrews M. Limbird TJ, Harper MC, Johnson K et al. Operative treatment of fractures of the tibial plafond: A randomized prospective study. J Bone Joint Surg Am 1996; 78:1646-1657.

6. Helfet DL, Koval K, Pappas J, Sanders RW, Dipasquale T. Intraarticular "pilon” fracture of the tibia. Clin Orthop 1994; 298:221-228.

7. Bone LB, Stegemann P, McNamara K. External fixation of severely comminuted and open tibial pilon fractures. Clin Orthop 1993; 292:101-107

8. Bonar SK, Marsh XL. Unilateral external fixation for severe pilon fractures. Foot Ankle Int 1993; 14:57-64.

9. Tornetta PI, Weiner L, Bergman M. Pilon fractures. Treatment with combined internal and external fixation. J Orthop Trauma 1993; 7:489-496.

10. Saleh M, Shanahan, Fern ED. Intraarticular fractures of the distal tibia. Surgical management by limited internal fixation and articulated distraction. Injury 1993; 24(1):37-40.

11. Barbieri R, Scbenk R. Koval K, Aurori K, Aurori B. Hybrid external fixation in the treatment of tibial plafond fractures. Clin Orthop 1996;332:16-22.

12. Gaudinez RF, Mallikar, Szporn M. Hybrid external fixation in tibial plafond fractures. Clin Orthop 1996 Aug; 329:223-232.

13. Anglen JO. Early outcome of Hybrid External Fixator for the fractures of distal tibia. J Orthop trauma 1999 Feb; 13 (2): 92-97.

14. Kevin J Pugh, Philip R Wolinsky, Mark P McAndrew. Tibial pilon fractures: A comparison of treatment methods. J Trauma 1999; 47 (7): 937-941.

15. French B, Tornetta P. Hybrid external fixation of tibial pilon fractures. Foot Ankle Clin 2000; 5(4): 2000.

16. Yang M, Nayagam S, Saleh M. Stiffness characteristics and interfragmentary displacement with different hybrid external fixators .Clin Biomech (Bristol, Avon)2003; 18(2): 166-172.

17. Piper KJ, Won HY, Ellis AM. Hybrid external fixation in complex tibial plateau and plafond fractures: an Australian audit of outcome. Injury 2005; 36 (1): 178-84.

18. Sirkin MS, Bono CM, Reilly MC, Behrens FF. Percutaneous Methods of Tibial Plateau Fixation. Clinical Orthopaedics and Related Research June 2000 ;Volume 375:60-68

19. Ruedi TP, Allgower M. The operative treatment of intra articular fractures of the lower end of tibia. Clin Orthop 1979; 138:105-110.

20. Maurice E Muller. Classification of fractures of long bones 1Ed: Springer Berlin Hiedelberg; 1990

21. Wood GW II. General Principles of Fracture Treatment. In: Terry Canale. Campbell's Operative Orthopaedics. 11th ed. St Louis: Mosby; 2000.p.3018-3085.

22. Marsh JL, Saltzman CL. Ankle fractures. In: Bucholz RW, Heckman JD,Court-Brown CM. Rockwood and Green's fractures in Adults, 6th ed. Philadelphia: Lippincott, Williams and Wilkins; 2001.p.2148-2247.

23. Court Brown CM, Walker C Garg A. Half ring external fixation in the management of tibial plafond fractures. J Orthop Trauma 1999; 13 (3): 200-206.

24. Olson SA, Christopher G, Finkemeier, Moehring DH. Open fractures. In: Bucholz RW, Heckman JD and Court-Brown CM. Rockwood and Green's Fractures in Adults. 6th ed. Philadelphia: Lippincott, Williams and Wilkins; 2006.p.319-424.

25. Olson SA, Christopher G, Finkemeier, Moehring DH. Open fractures. In: Bucholz RW, Heckman JD and Court-Brown CM. Rockwood and Green's Fractures in Adults. 6th ed. Philadelphia: Lippincott, Williams and Wilkins; 2006.p.319-424.

26. Fred Behrens, Kate Searls. External fixation of tibia: Basic concepts and prospective evaluation. J Bone Joint Surg (British) 1986; 68 (B): 246-54.

27. Gaudinez, RF,Mallik, Arati R,Szporn Monroe. Hybrid External Fixation of Comminuted Tibial Plateau Fractures. Clin Orthop July 1996; Volume 328:203-210.

28. Anglen JO. Early outcome of Hybrid External Fixator for the fractures of distal tibia. J Orthop trauma 1999 Feb; 13 (2): 92-97.

29. Mayil natarajan, Selvaraj, Pasupathy, Chethan Nagaraj, Antony Vimalraj, Management of periarticular fractures if long bones of lower extremity by hybrid external fixation. IJO 2006; Vol 40 :3; 177-79

30. McFerran MA, Smith SW, Boulas HJ, Schwartz HS.Complications encountered in the treatment of pilon fractures.*J Orthop Trauma* 1992 ; 6 : 195-200.

31. Ocku G, Aktuglu K: Intraarticular fractures of the tibial plafond.
A comparison of the results using articulated and ring external fixators. *J Bone Joint Surg Br* 2004, 86B:868-75

32. Kapukaya a., Subasi m. and Arslanh.: Management of comminuted closed tibial plafond fractures using circular external fixators. Acta. Orthop. Belg., 71, 582- 589, 2005.

33. Chen S.H., Wu P.H. And Lee Y.S.: Long-Term Results Of Pilon Fractures. Arch. Orthop. Trauma Surg., 2007; 127: 55-60.

34. Vidyadhara S. And Rao S.K.: Ilizarov Treatment Of Complex Tibial Pilon Fractures. International Orthopaedics (Sicot), 30: 113-117, 2006.

35. French B, Tornetta P. Hybrid external fixation of tibial pilon fractures. *Foot Ankle Clin* 2000 ; 5 : 853-871.

36. Mast JW, Spiegel PG, Pappas JN. Fractures of tibial pilon. Clin Orthop 1988; 230: 68-82.

37. Collinge C, Kuper M, Larson K, Protzman R .Journal of Orthopaedic Trauma. July 2007; 21(6):355-361.

38. Grose A, Gardner M, Hettrich C, Fishman F, Lorich D, Asprinio D et al Journal of Orthopaedic Trauma. September 2007; 21(8):530-537.

39. Zeman J, Matejka J. Use of a hybrid external fixator for treatment of tibial fractures. Acta Chir Orthop Traumatol Cech 2005;72(6):337-43.

40. Aggarwal AK, Nagi ON. Hybrid external fixation in periarticular tibial fractures. Good final outcome in 56 patients. Acta Orthop Belg. 2006 Aug;72(4):434-40.

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ANNEXURE

PATIENT CONSENT FORM

Study detail :"Functional Analysis Of **Distal Tibial Fractures Treated With Hybrid external Fixator**"

Study centre : Government Royapettah Hospital,Chennai

Patients Name :

Patients Age :

Identification Number :

Patient may check (✓) these boxes

I confirm that I have understood the purpose of procedure for the above study. I have the opportunity to Ask question and all my questions and doubts have been answered to my complete satisfaction. ☐

I understand that my participation in the study is voluntary and that I am free to withdraw at any time without giving reason, without my legal rights being affected. ☐

I understand that sponsor of the clinical study, others working on the sponsor's behalf, the ethical committee and the regulatory authorities will not need my permission to look at my health records, both in respect of current study and any further research that may be conducted in relation to it, even if I withdraw from the study I agree to this access. However, I understand that my identity will not be ☐

revealed in any information released to third parties or published, unless as required under the law. I agree not to restrict the use of any data or results that arise from this study.

I hereby make known that I have fully understood the use of the implant, the possible complications arising out of its use and the same was clearly explained to me and also understand that the use of this implant is An accepted method of treatment of fractures and this study is done to know the usefulness of this implant in management of distal tibial fractures. ☐

I agree to take part in the above study and to comply with the instructions given during the study and faithfully cooperate with the study team and to immediately inform the study staff if I suffer from any deterioration in my health or well-being or any unexpected or unusual symptoms. ☐

I hereby consent to participate in this study. ☐

I hereby give permission to undergo complete clinical examination and diagnostic tests including hematological, biochemical, radiological tests. ☐

Signature/thumb impression:

Patients Name and Address: place date

Signature of investigator :

Study investigator's Name : place date

PROFORMA

Name	:	
Age / Sex	:	
IP number	:	
Address	:	
Contact Number	:	
Date of Admission	:	
Date of Surgery	:	
Date of Discharge	:	
Occupation	:	
Education	:	
Socioeconomic Status	:	
Diagnosis	:	

Procedure Done :

HISTORY:

1. Mode of injury : Road traffic accident / Fall at home / Fall from height / Assault
2. Presenting complaints :
    a. Pain – site / duration
    b. Swelling – site / extent
    c. Deformity
    d. Disturbances in function – movements
    e. Other associated injuries – head injury / limb injuries / spine injuries
3. Medical Co morbid illnesses :
4. Drug history : Steroids / Disease modifying anti-rheumatoid drugs / Immunosuppressant's

PAST HISTORY:

- ➢ Any similar injuries
- ➢ Previous surgeries or hospitalisations
- ➢ Any major illnesses

PERSONAL HISTORY:

OBSTETRIC & GYNAECOLOGY HISTORY:

TREATMENT HISTORY:

FAMILY HISTORY:

CLINICAL EXAMINATION:

GENERAL EXAMINATION:

VITALS:

Pulse : BP :

SYSTEMIC EXAMINATION :

- ☞ Cardiovascular system : Respiratory system :
- ☞ Abdomen : Central nervous system :

REGIONAL EXAMINATION

RIGHT / LEFT LEG & ANKLE :

External injury-grading :

Swelling :

Tenderness :

Deformity :

Abnormal mobility :

Crepitus :

Distal pulse :

Toe /ankle extension

Other injuries :

X – RAY FINDINGS:

X-ray R/L leg with ankle :

INVESTIGATIONS

Hb%	TC	DC
ESR	BT/CT	RBS
Urea	S.creatinine	Electrolytes
HBsAg	HIV	VDRL
CXR	ECG	Urine routine
Blood G & T	ECHO	Albumin
		Sugar
		Deposits

FINAL DIAGNOSIS:

INITIAL TREATMENT GIVEN:

PLANNED SURGERY :

PROCEDURE NOTES :

POST OP PERIOD

FOLLOW UP ANALYSIS:

FOLLOW UP (After discharge)	Ovadia & Beals		Pin tract infection	Radiological evaluation	Advice
	objective	subjective			
FIRST WEEK					
SECOND WEEK					
FIRST MONTH					
SECOND MONTH					
THIRD MONTH					
SIXTH MONTH					

Outcome : As per Ovadia & Beals Criteria – Objective & Subjective evaluation

I – excellent   II – good

III – fair   IV – poor
